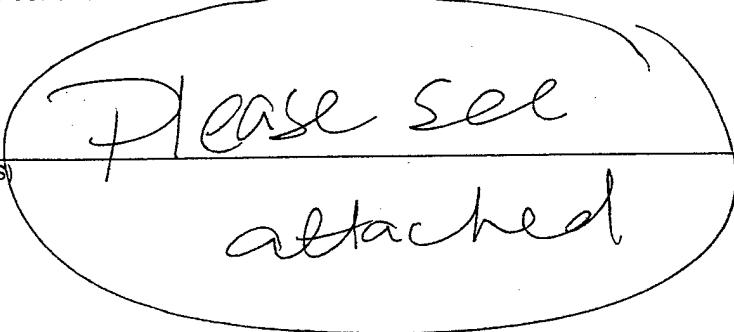


REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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			5b. GRANT NUMBER	
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14. ABSTRACT				
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			19a. NAME OF RESPONSIBLE PERSON	Leilani Richardson
			19b. TELEPHONE NUMBER (include area code)	(661) 275-5015

1011CA 9F

MEMORANDUM FOR PRS (In-House/Contractor Publication)

FROM: PROI (STINFO)

19 Apr 2001

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-VG-2001-096**
Shawn H. Phillips; Timothy S. Haddad; Rusty L. Blanski, "New Multi-Functional Materials Using
Versatile Hybrid (Inorganic/Organic) POSS Nanotechnology"

International Symposium – SAMPE
(Long Beach, CA, 08 May 2001) (Deadline: 08 May 01)

(Statement A)

1. This request has been reviewed by the Foreign Disclosure Office for: a.) appropriateness of distribution statement, b.) military/national critical technology, c.) export controls or distribution restrictions, d.) appropriateness for release to a foreign nation, and e.) technical sensitivity and/or economic sensitivity.

Comments: _____

Signature _____ Date _____

2. This request has been reviewed by the Public Affairs Office for: a.) appropriateness for public release and/or b) possible higher headquarters review.

Comments: _____

Signature _____ Date _____

3. This request has been reviewed by the STINFO for: a.) changes if approved as amended, b) appropriateness of references, if applicable; and c.) format and completion of meeting clearance form if required

Comments: _____

Signature _____ Date _____

4. This request has been reviewed by PR for: a.) technical accuracy, b.) appropriateness for audience, c.) appropriateness of distribution statement, d.) technical sensitivity and economic sensitivity, e.) military/national critical technology, and f.) data rights and patentability

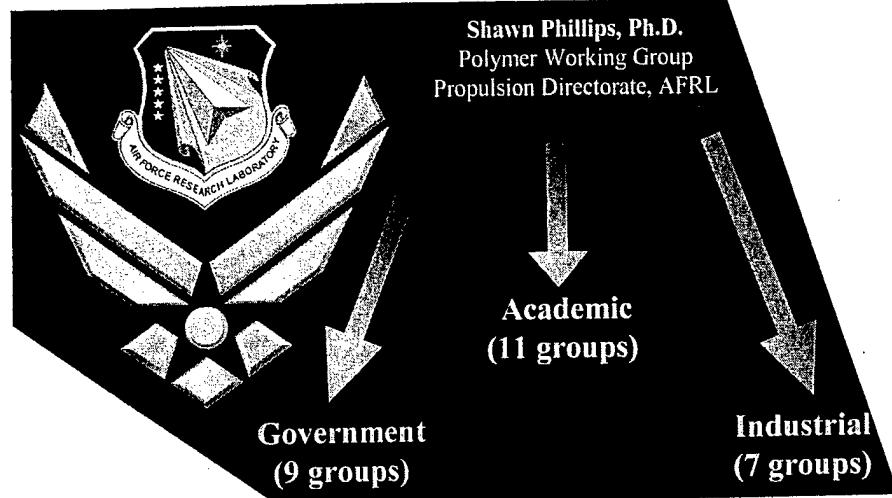
Comments: _____

APPROVED/APPROVED AS AMENDED/DISAPPROVED

PHILIP A. KESSEL
Technical Advisor
Space and Missile Propulsion Division

Date

*New Multi-Functional Materials Using
Versatile Hybrid (Inorganic/Organic)
POSS Nanotechnology*
Angstro™



Acknowledgements

Polymer Working Group

Dr. Tim Haddad*
Dr. Rusty Blanski*
Dr. Brent Viers*
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Brian Moore*
Capt Steve Svejda, Ph.D.
Justin Leland
Pat Ruth
New Post-Doc: Polymer Synthesis

Edwards

Dr. Kevin Chaffee
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Mr. Hieu Nguyen

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Dr. Joe Lichtenhan - HP
Dr. Joe Schwab - HP
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Dr. Jeff Gilman* - NIST
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Prof. Bryan Coughlin* - UMass
Prof. Gar Hoflund - UF
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Dr. Rich Vaia* - AFRL/MLBP
Dr. Seng Tan - WMR
Prof. Mark Gordon* - Iowa St. U
Dr. Howard Katzman - Aerospace
Mr. Don Geidt/Mike Blair - CSD/Thiokol

Funding: AFOSR (Dr. Charles Lee), AFRL, Hybrid Plastics

Basic R&D

Applications R&D

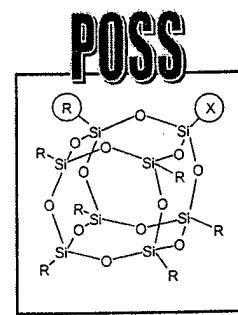
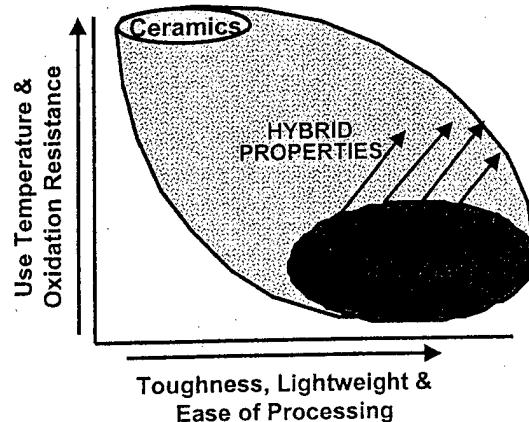
*"Hot" Topics in
Propulsion/Air Force Materials*

POSS Nanostructured Polymers



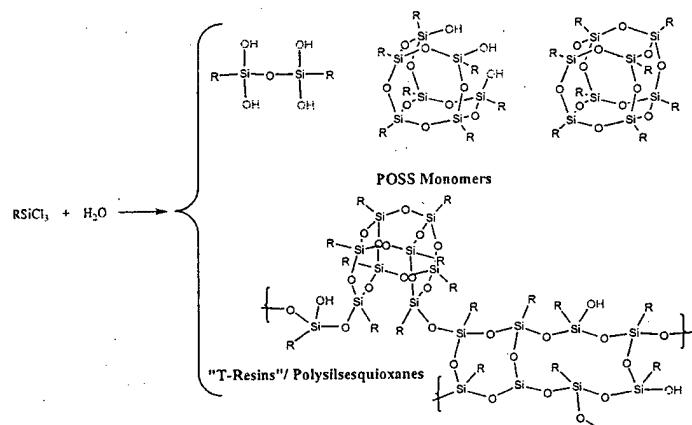
- High Temperature Insulation for Solid Rocket Motors
- Capacitors
- High Temperature/Lightweight Jet Canopies
- Space-survivable Materials and Coatings
- Low/High Temp. Hybrid Lubricants
- Plastic Tubing and Ducting for Liquid Rocket Engines
- High Temperature/High Translation Strength Composites
- Improved Radome Materials

*Multiple Applications/
Multi-Function*



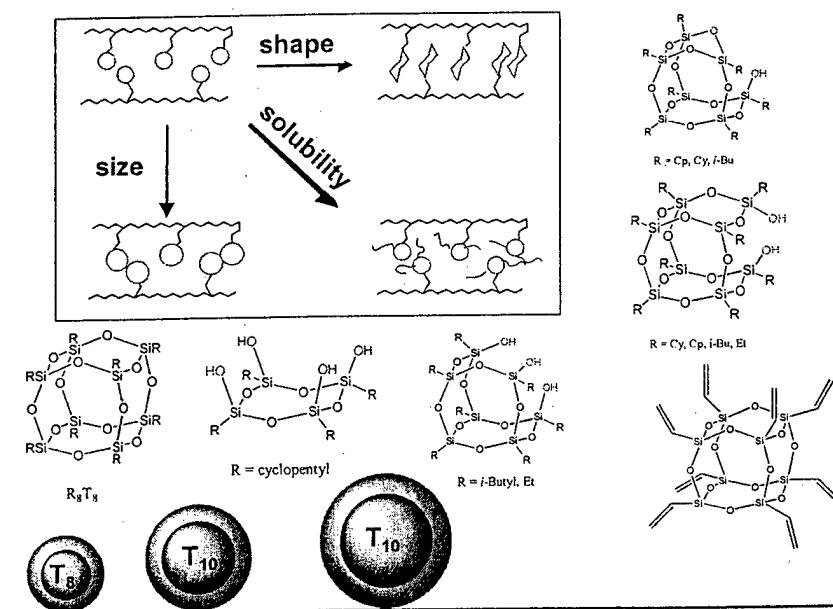
- Improve High Performance Polymers
- Transform Commodity Polymers into High performance Polymers
- Develop Multi-Functional Materials

POSS Feedstocks



- R = Cyclohexyl, t = 3-36 (48 months)
- R = Cyclopentyl, t = 11 days!
- No other incompletely condensed silsesquioxanes

Existing POSS-Polymers: Structure/Property Relationships



Property Enhancements via POSS

Observed in POSS-Copolymers and Blends

increased T_g

reduced
flammability

reduced
heat evolution

lower density

disposal
as silica

increased T_{dec}

extended
temperature range

increased
oxygen permeability

lower thermal
conductivity

thermoplastic
or curable

enhanced blend
miscibility

oxidation
resistance

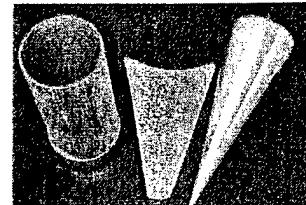
altered
mechanicals

reduced
viscosity

Beat
competitors'
patents!

6.2 (IHPPT): Solid Rocket Motor Insulation

Case Insulation



POSS-Insulation Sample

Goal: 50% Lower Erosion of Insulation (44 % weight reduction,
7.4% booster payload increase) – Phase III IHPPT

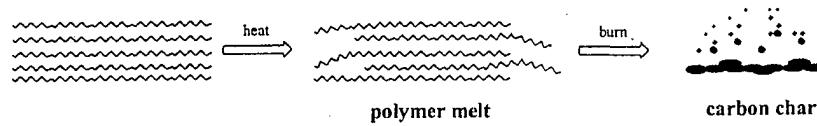
Objective: Development of Ceramic Forming Polymer

POSS-Polymer Insulation - Advantages:

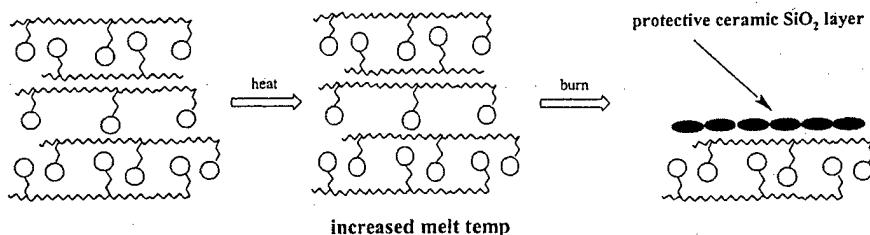
- High loadings of POSS can be incorporated without embrittlement
- Si to O ratio is 1:1.5, proven to oxidize up to 1:2 (SiO₂)
- Tailorability of POSS monomers improve physical/mechanical properties
- Capabilities for Large and Small scale testing (Hybrid Plastics)

POSS for Flame Retardant Materials

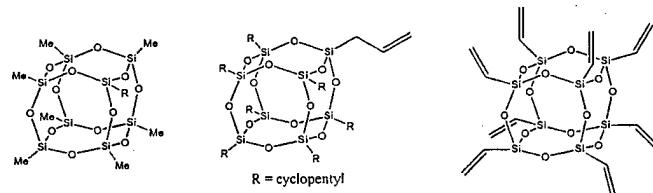
Traditional Polymer



POSS Polymer

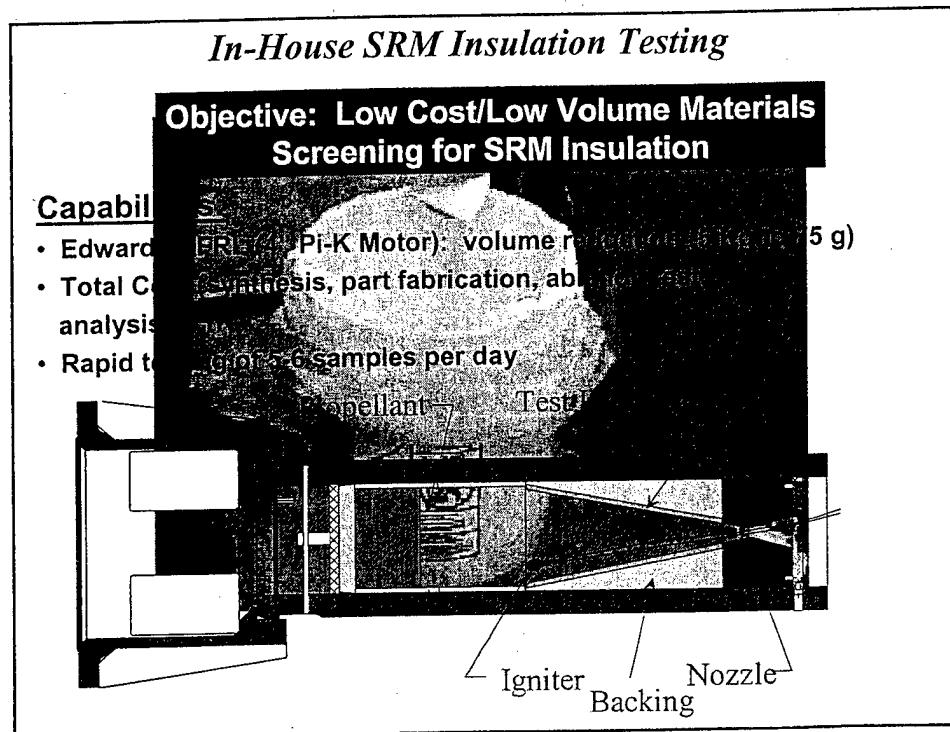
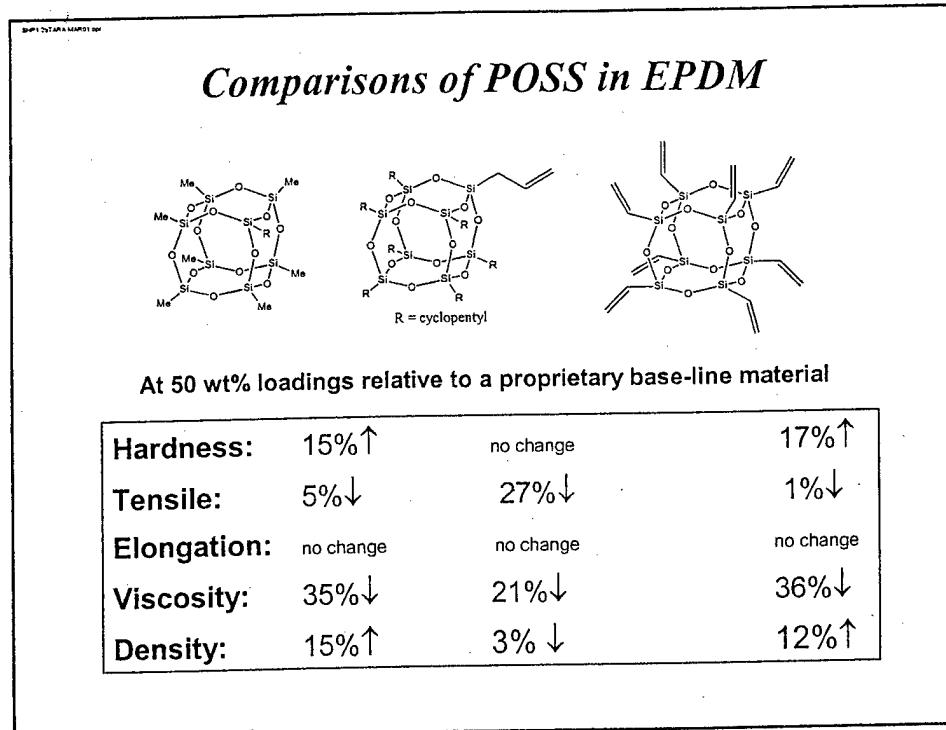


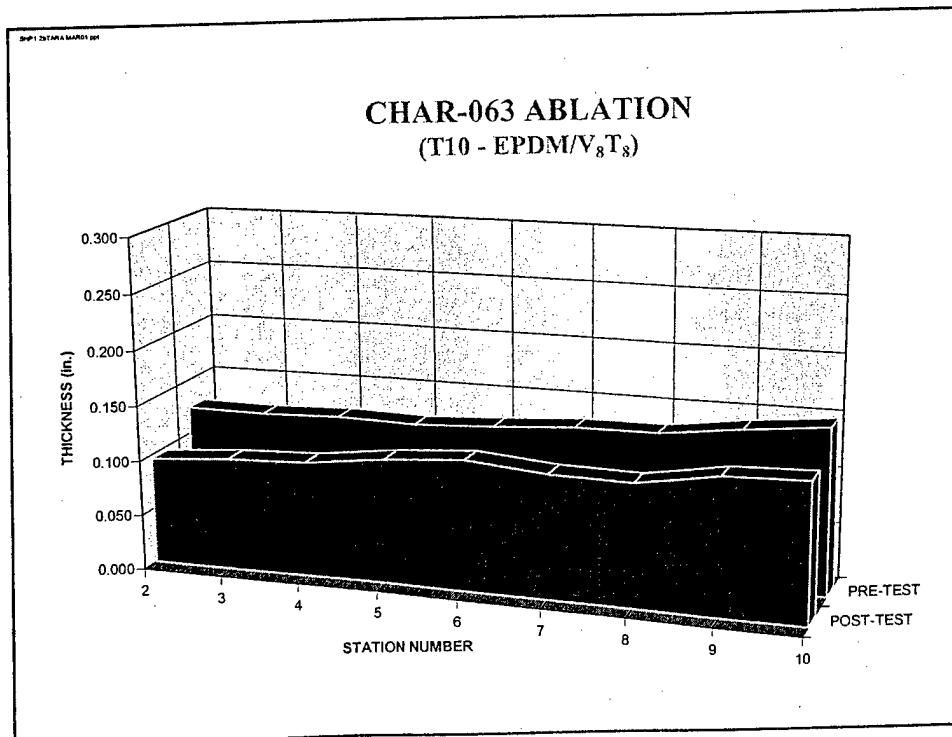
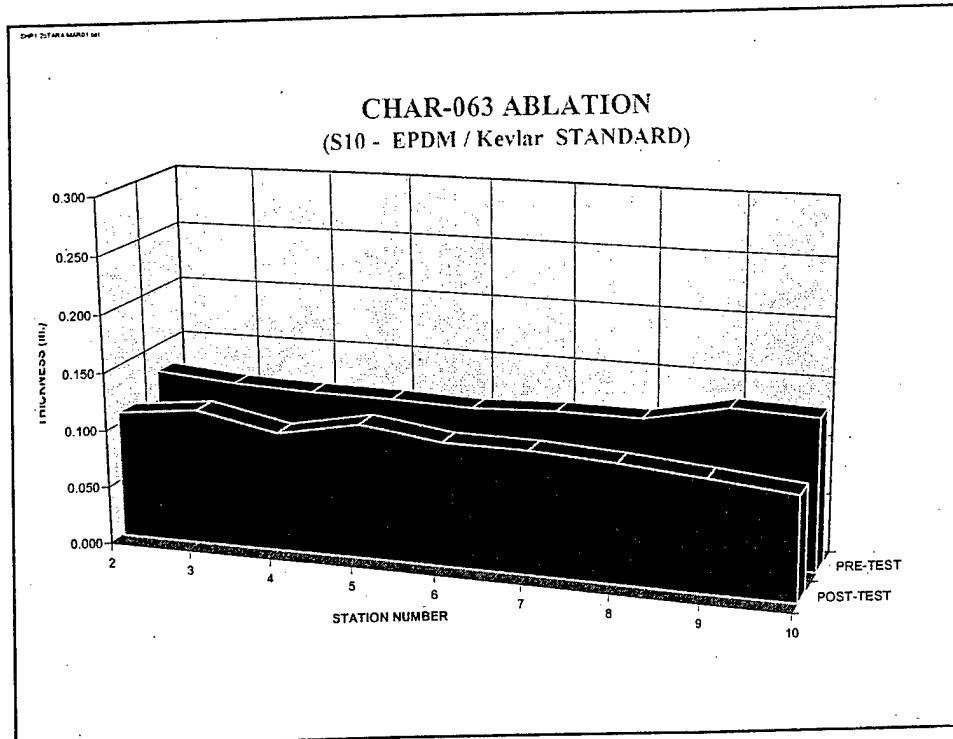
Comparisons of POSS in EPDM

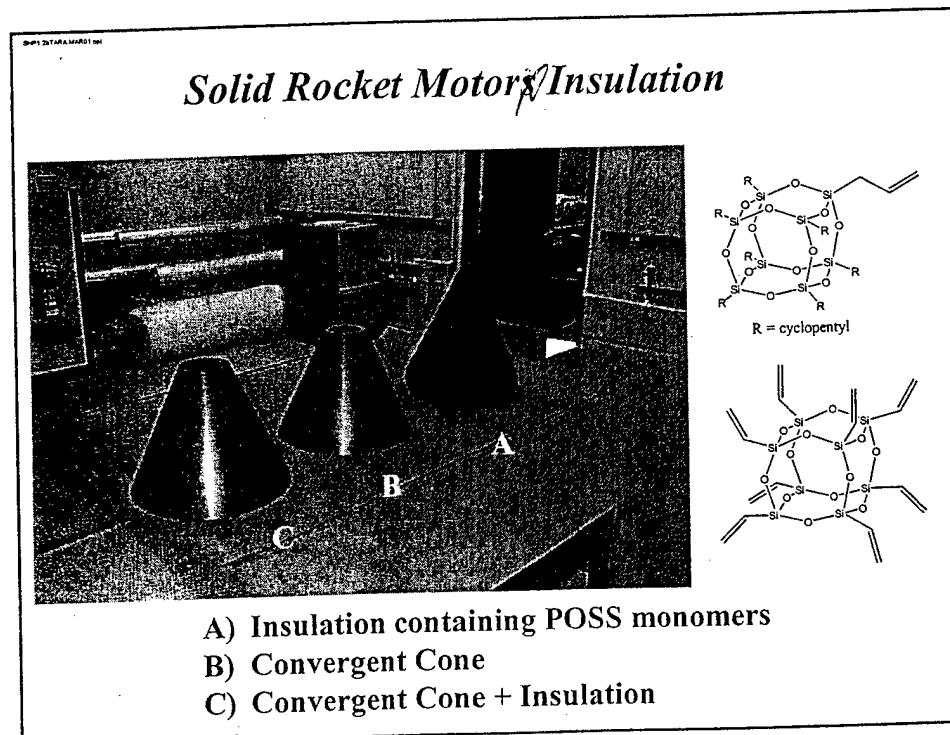
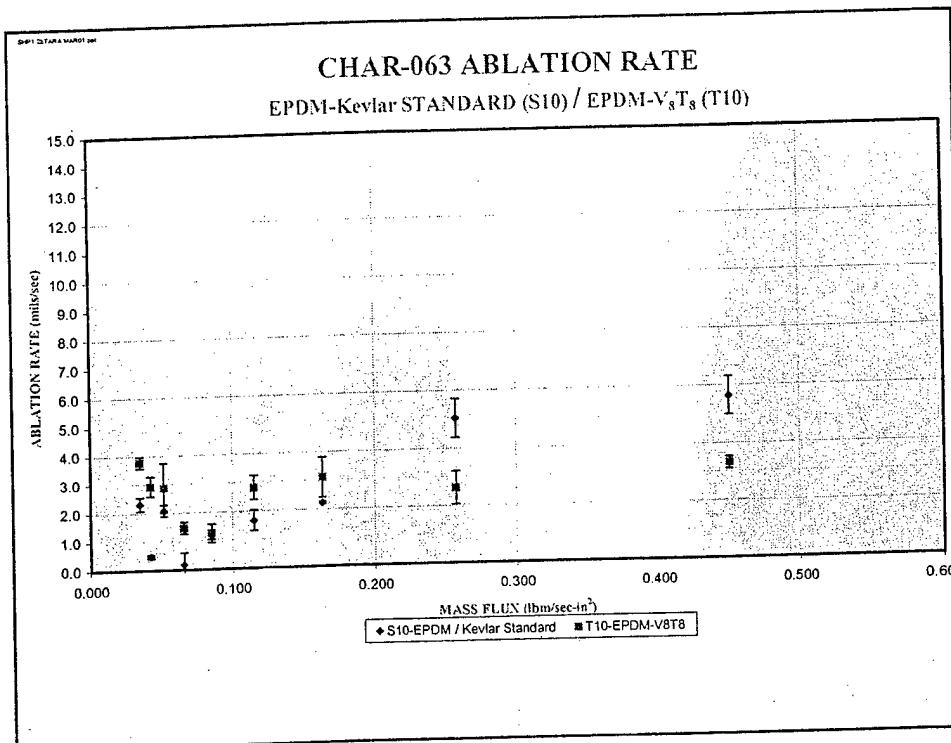


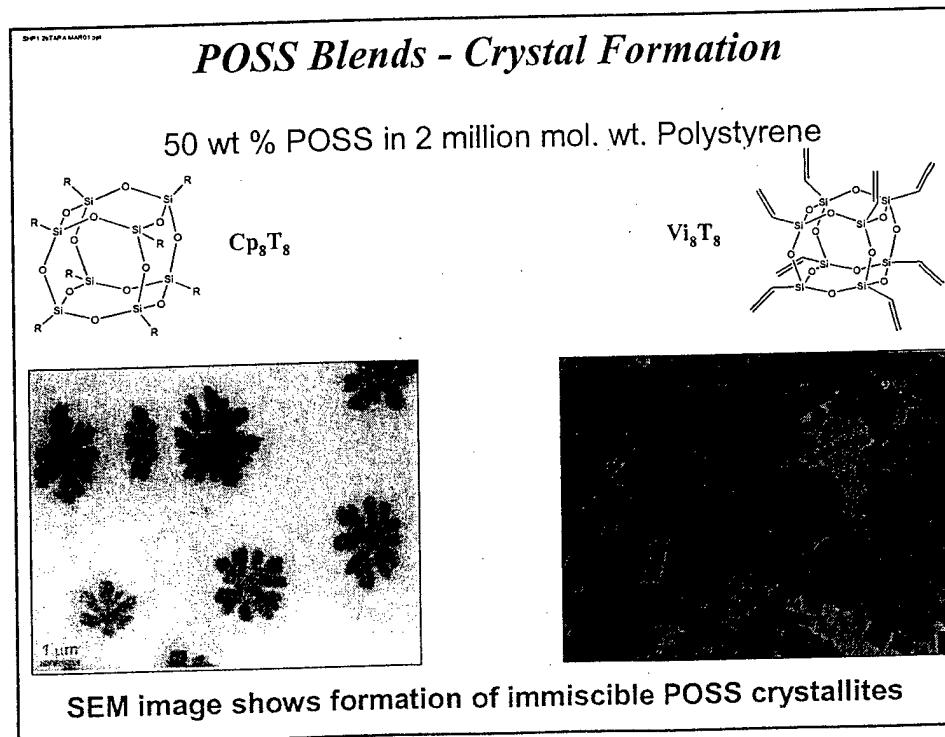
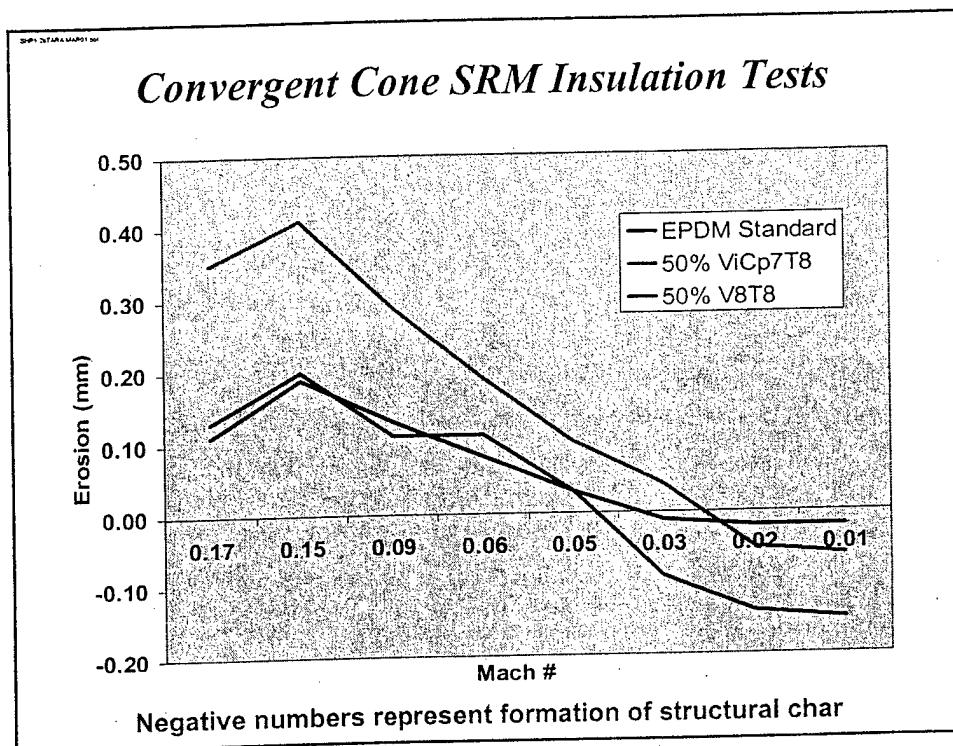
At 25 wt% loadings relative to a proprietary base-line material

Hardness:	12%↑	no change	no change
Tensile:	17%↓	17%↓	---
Elongation:	no change	no change	no change
Viscosity:	42%↓	39%↓	36%↓
Density:	9%↑	3% ↓	3% ↓



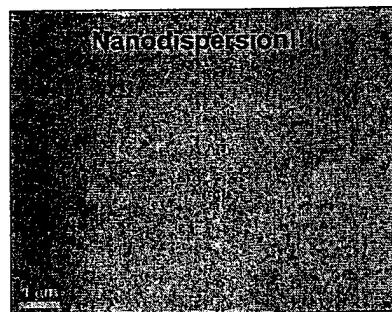
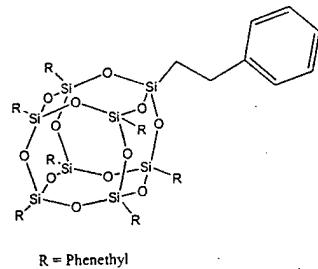






POSS Blends - Miscibility

50 wt % Phenethyl₈T₈ in 2 million mol. wt. Polystyrene



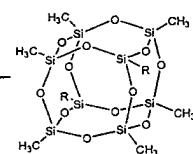
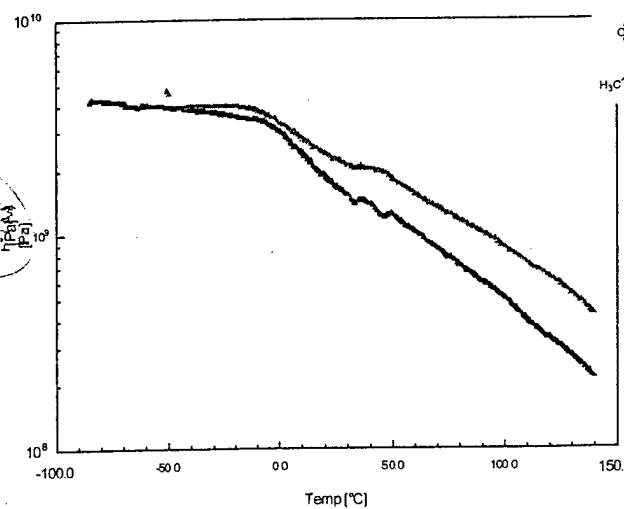
- Catalytic hydrogenation of Styryl₈T₈
- Demonstrated Complete Miscibility!!
- No POSS crystallites by SEM or X-ray!!



Scale-up, incorporation and testing polymer systems

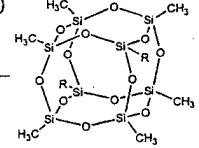
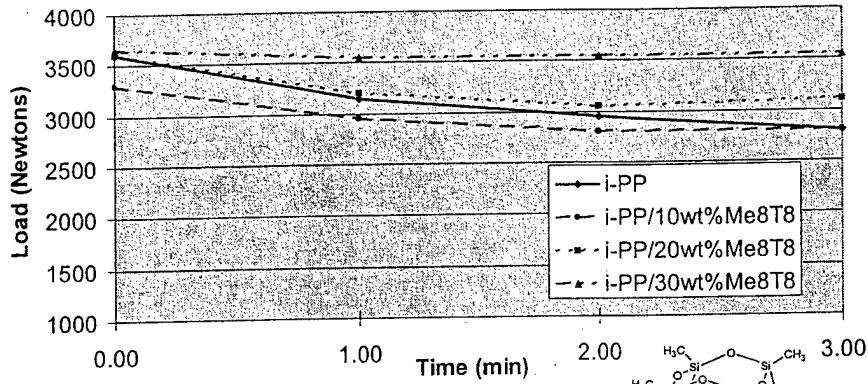
i-PP/Me₈T₈ Processing Studies

Neat Polypropylene and Blended with POSS nano-filters



i-PP/Me₈T₈ Processing Studies

iso-Polypropylene w/ Me8T8

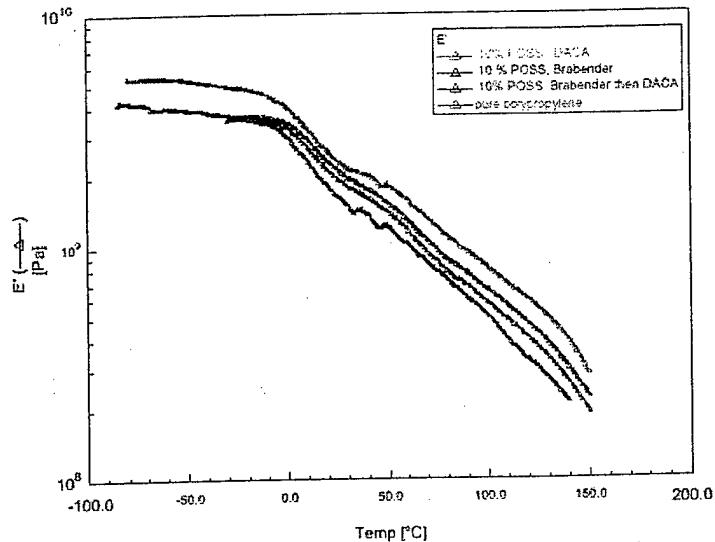


Prof. Andre Lee - Michigan State University

	Dow data	Neat <i>i</i> -PP (processed)	<i>i</i> -PP blended 2 wt% Methyl ₈ T ₈	<i>i</i> -PP blended 5 wt% Methyl ₈ T ₈	<i>i</i> -PP blended 10 wt% Methyl ₈ T ₈
Tensile Strength @ Yield; ASTM D638	5000 psi (34.5 MPa)	4800 psi (33.0 MPa)	5000 psi (34.5 MPa)	5100 psi (35.1 MPa)	5200 psi (35.8 MPa)
Flexural Modulus (0.05 in/min, 1% secant); ASTM D790A	240,000 psi (1.655 GPa)	235,000 psi (1.620 GPa)	251,000 psi (1.730 GPa)	255,000 psi (1.757 GPa)	262,000 psi (1.80 GPa)
HDT @ 66 psi, as injected; ASTM D648	210 °F (99 °C)	210 °F (99 °C)	221 °F (105 °C)	239 °F (115 °C)	255 °F (124 °C)
Impact Izod @25C ASTM D256A	0.5 ft-lb/in	0.55 ft-lb/in	0.55 ft-lb/in	0.62 ft-lb/in	0.75 ft-lb/in

- The above data (other than Dow's data) is an average of at least 10 samples for each test with acceptable S.D. of 5% or better.

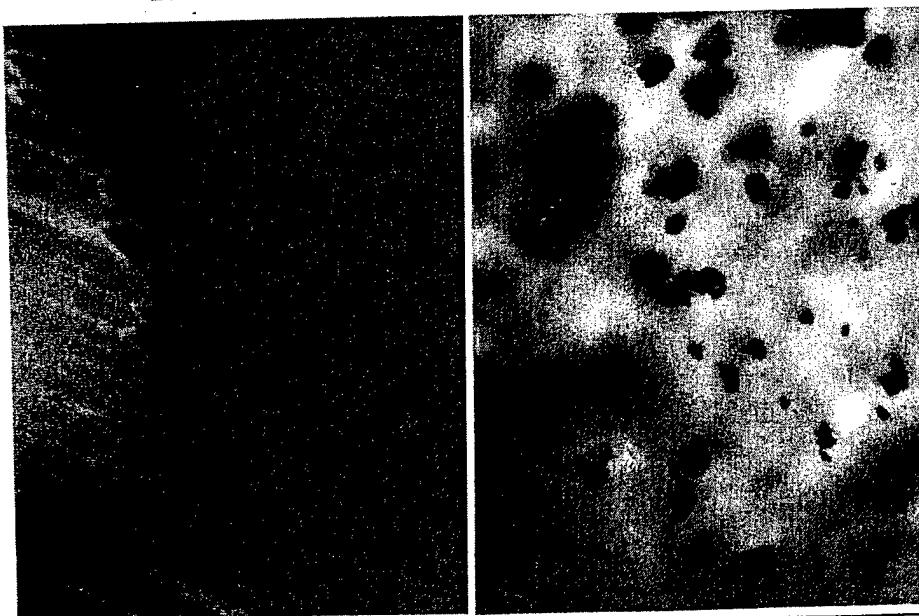
i-PP/Me₈T₈ Processing Studies



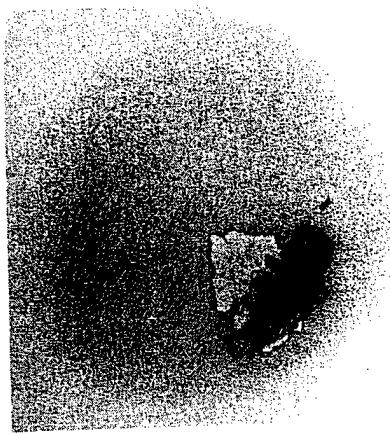
i-PP/Me₈T₈

Brabender

Twin-Screw Extruder



Shaw Industries i-PP/Me8T8 Fiber



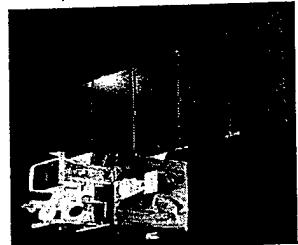
Nanodispersion of Me8T8 around defect/dirt?

POSS-iPP Summary

Prof. Ben Hsiao: SWAXS Studies

- 1) Some evidence of molecular dispersion of POSS in iPP - probably due to the favorable entropy of mixing between R (-CH₃) and the iPP chains
- 2) Half time of crystallization decreases by two orders of magnitude by flow (10² vs. 10⁴ s). The addition of POSS further reduced the crystallization time - an indication of POSS being true molecular orientation enhancing agents (real nanocomposites)
- 3) In typical polymer processing, only the chains longer than M* can be oriented; chains shorter than M* remain unoriented due to fast relaxation. The addition of POSS appears to reduce the value of M* - more studies are needed!

Goal: Develop Multi-Functional, Space-Survivable Materials



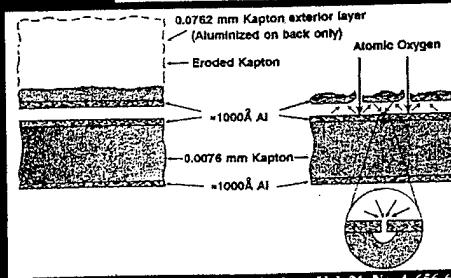
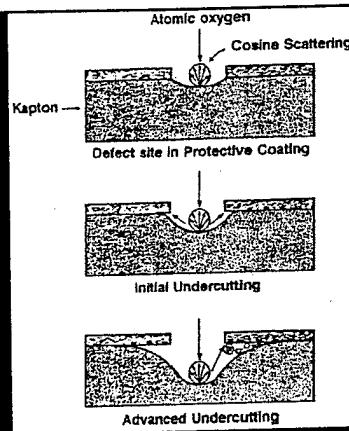
Satellites & Space Systems

Bond	Dissociation Energy (eV)	λ (nm)	Material
$-C_6H_4-C(=O)-$	3.9	320	Kapton®
C-N	3.2	390	Kapton®
CF_3-CF_3	4.3	290	FEP Teflon®
CF_2-F	5.5	230	FEP Teflon®
Si-O	8.3	150	Nanocomposite
Zr-O	8.1	150	Nanocomposite
Al-O	5.3	230	Nanocomposite

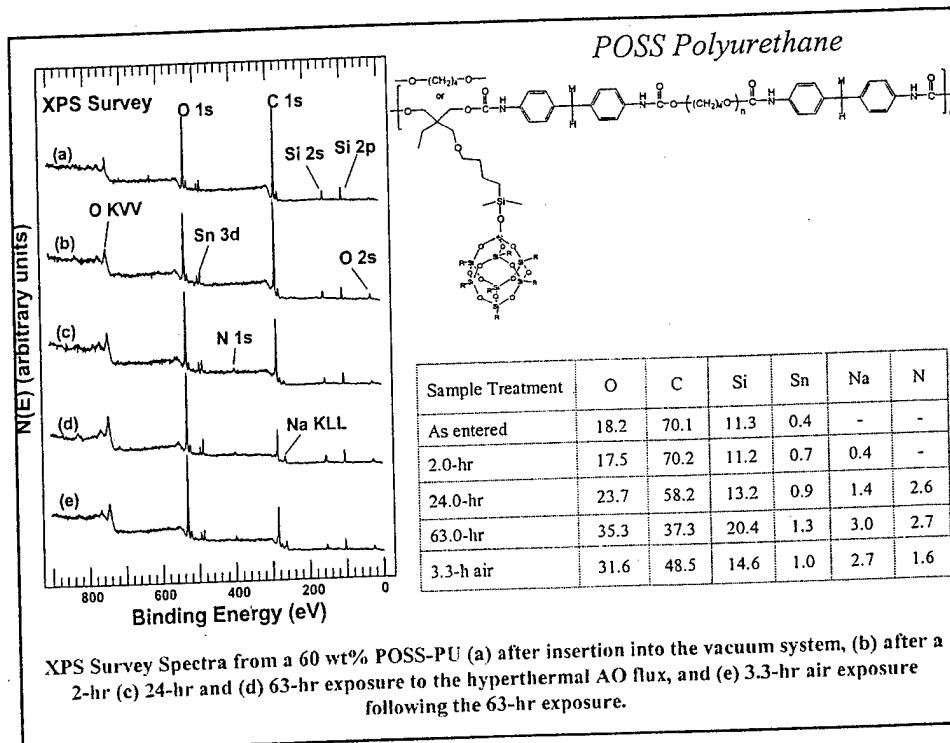
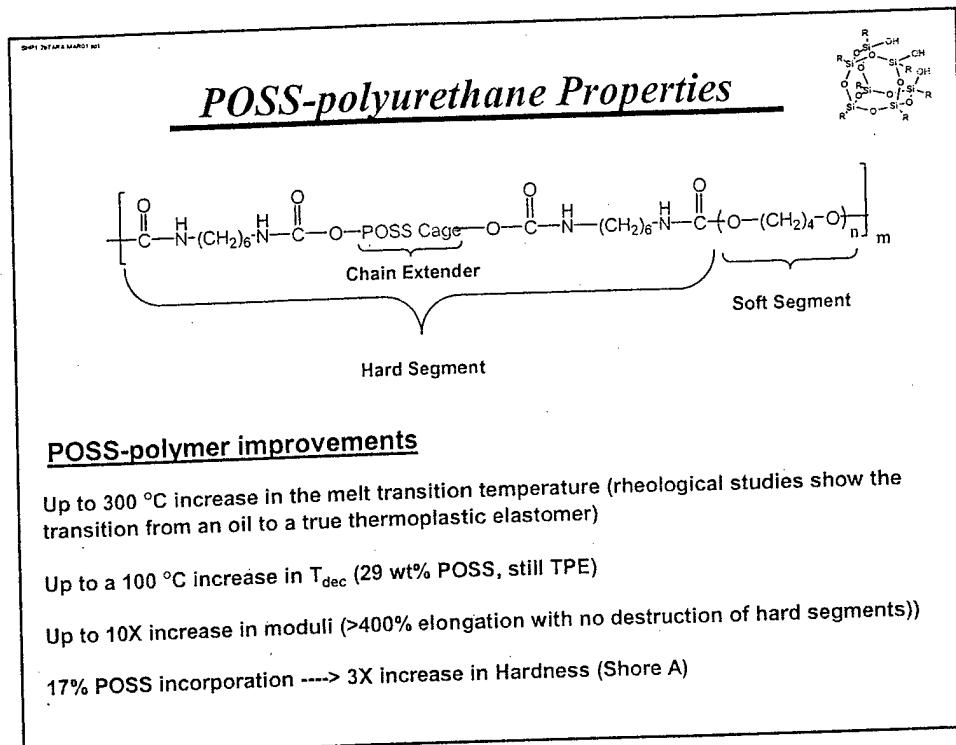
Objectives

- Increase Space Resistance (AO, particle & VUV radiation, thermal cycling) of Polymeric Materials by 10x
- Self-Passivating/Self-Rigidizing/Self-Healing based on nanocomposite incorporation

AO undercutting of LDEF Aluminized-Kapton Multilayer Insulation



Groh, K.K., Banks, B.A., J. Spacecraft and Rockets, Vol. 31, No. 4, 656-664 (1994)



Summary

- Successfully demonstrated multi-functionality of POSS utilizing both mechanical and physical properties
- We are looking into multiple applications for inorganic particles both as blends and copolymers
- Hybrid Plastics has been extremely successful in reducing the cost and increasing the production of POSS monomers
- Only with continued development of POSS monomers can we hope to control/predict property enhancements